# PROGRAM OF LAKE OKEECHOBEE INVESTIGATIONS

DRE-26

Central and Southern Florida Flood Control District

Resources Planning Department

June, 1973

## TABLE OF CONTENTS

## LIST OF FIGURES



## LIST OF TABLES

## INTRODUCTION

Lake Okeechobee is located in the center of the Florida peninsula approximately 200 miles north of the southern tip. The Lake measures about 37 miles long and 30 miles wide, with the long axis running north and south. The surface area is about 730 square miles, or 460,000 acres.

The average depth of the Lake is about 10 feet. The bottom elevations range from sea level to about 15 ft. msl. The basin is shaped like a very shallow saucer with well over half the bottom being at 5 ft. msl. or less. The southern and western shores of the Lake consist of very extensive marsh areas. A much smaller marsh area is found along the northeast shore of the Lake.

The drainage area of the Lake is now about 5,300 square miles. This includes both the natural drainage area (primarily the Kissimmee River - Lake Istokpoga basin) and forced drainage from agricultural areas southeast of the Lake.

Lake Okeechobee is completely enclosed by an 80-mile levee system with control structures at most major inflows and outflows. Water releases to and from the Lake are made on the basis of water supply and flood control criteria.

Presently the regulation schedule is to maintain the Lake at about 15.5 ft. msl. from November to March, and drop the level to about 14.0 ft. msl. during the summer months. In reality, it is very difficult to maintain the Lake level at regulation stage, and the level will vary from 10 to 17 ft. msl.

Lake Okeechobee is the major reservoir in the water system of south Florida, and is currently being placed under stress from both increasing

nutrient input and proposed changes in maximum Lake stage. It is hoped that the effects of such stresses can be understood as fully as possible in order to develop a rational approach to the protection of the natural system functioning in the Lake.

The impact of such stresses on Lake Okeechobee cannot be evaluated without a comprehensive understanding of how the natural system functions. In working toward such an understanding, the natural system may be arbitrarily divided into three zones; (1) Littoral, (2) Limnetic, (3) Benthic. Within each zone interaction occurs among flora, fauna, and water.

The purpose of this study is to increase our knowledge of the various natural systems within the Lake and of the interactions between the systems. Hopefully, the results of the study will allow the consideration of water quality criteria as well as water supply and flood control criteria in the management of Lake Okeechobee as a natural resource.

## LIMNETIC ZONE

### LIMNETIC PRODUCTIVITY

Limnetic productivity studies are an integral part of the overall monitoring program on the Lake. Productivity will be studied most intensively at the first trophic level. Primary productivity is concerned with the capacity of an ecosystem to build up primary organic compounds of high chemical potentials at the expense of external energy sources. This involves both photosynthesis and autotrophic chemosynthesis. As the names indicate, physical and chemical conditions are important factors in these processes. The effects of these factors on the biosphere are first observed at the first trophic level. For this reason, all primary productivity studies will be coordinated with the water quality monitoring program.

The "primary producers" responsible for the build-up of primary organic compounds are themselves generally indicative of water quality. The enumeration and identification of these producers, mainly phytoplankton, are instrumental in determining the quality of the water present. A few phytoplankton, under certain conditions, will "bloom", resulting in undesirable changes in the water. This may take the form of repugnant tastes and odors, or more drastically, fish kills. By monitoring the changes in phytoplankton populations and physicochemical parameters of the water, we may be able to predict and possibly avert these undesirable changes.

The second trophic level, primary consumers, will be studied in less detail. The primary consumers are zooplankton which feed upon phytoplankton. Their numbers reflect the influence of water quality on the basal animal population in the limnetic zone.

Since they reflect substrate as well as water quality, benthic organisms will be studied in detail.

Primary productivity studies will be carried out at monthly intervals at Stations 1, 4, 5, and 6 as shown in Figure 1. At present, standard light and dark bottle techniques (oxygen method) appear to be adequate for measuring the Lake's productivity.

Raw water samples for phytoplankton analysis will be collected monthly at Stations 1-9 as shown in Figure 1.

Quantitative and qualitative analysis of zooplankton population will be determined quarterly at the primary productivity stations.

Quantitative and qualitative analysis of benthic organisms will be determined semi-annually at Stations 1-9.

## WATER QUALITY MONITORING

Monthly sampling at a limited number of stations on Lake Okeechobee will monitor water quality within the Lake and document relatively short term fluctuations in chemical parameters of the Lake.

The sampling stations are #1-9, as shown in Figure 1. Surface (0.5 meters) and bottom samples will be taken at each station. During the months of May and November the effectiveness of the nine stations chosen for monitoring will be judged by comparing their results with the results of all 16 stations shown in Figure 1.

The parameters to be monitored monthly include field, physical, major ions and nutrient determinations. Trace metal analysis will be added twice yearly during the months of January and June. Table 1 shows the parameters that are included in the general terms such as field, physical, major ion, nutrient and trace metal analysis. Dissolved organic carbon will be determined bi-monthly.

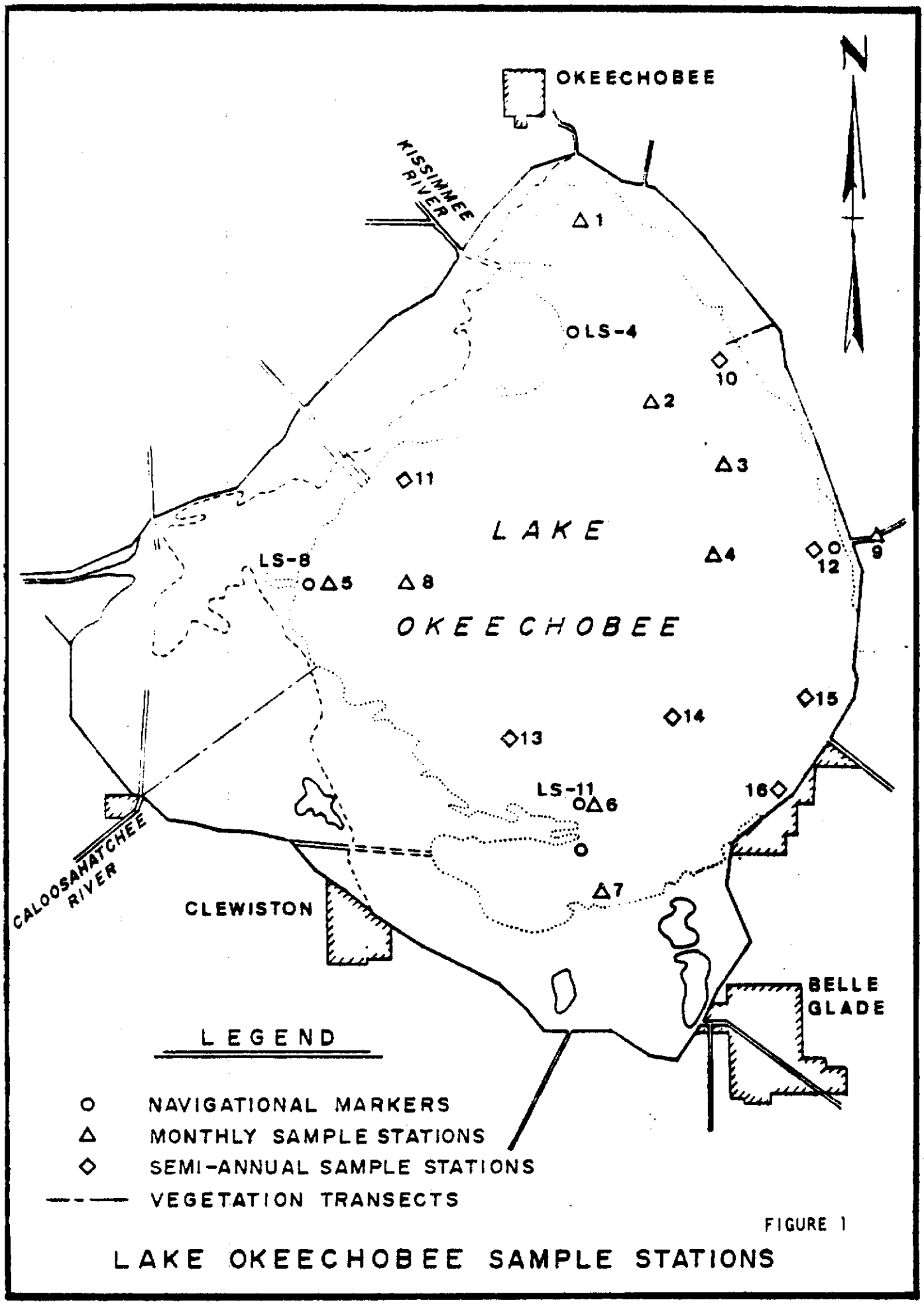


FIGURE 1

LAKE OKEECHOBEE SAMPLE STATIONS

TABLE 1

Chemical Parameters

| General Term | Specific Parameters |
|---|---|
| Field | Secchi Disc, Temperature, Dissolved Oxygen, pH, Specific Conductivity and Alkalinity. |
| Physical | Turbidity, Suspended Solids. |
| Major Ion | Sodium, Calcium, Magnesium, Chloride and Sulphate. |
| Nutrients | Dissolved Inorganic and Organic Phosphorus, Particulate Phosphorus, Dissolved Organic Nitrogen, Particulate Nitrogen, Nitrate, Nitrite, Ammonia and Reactive Silicate. |
| Trace Metals | Aluminum, Arsenic, Boron, Cadmium, Cobalt, Copper, Iron, Lead, Manganese, Mercury, Molybdenum, Nickel, Strontium and Zinc. |

## NUTRIENT AND DISSOLVED SOLIDS BUDGETS

Budgets for nutrients and dissolved solids in Lake Okeechobee will be calculated for each climatic cycle. The wet cycle will be considered the months from May to October and the dry cycle the months from November to April. The budgets will be calculated by assessing the quantity of nutrients and dissolved solids present in the Lake at the beginning of each cycle, monitoring the inputs and outputs of the Lake during the cycle, and determining the quantity remaining at the end of the cycle.

All major inputs and discharges from Lake Okeechobee will be monitored as shown in Figure 2. Weekly samples will be collected at each station by field station or pump station personnel. The results of the weekly samples will then be integrated over the six months budget cycle on the basis of flow data at each discharge point.

Major points of discharge (Kissimmee River, St. Lucie Canal and Caloosahatchee River) may periodically be sampled at more frequent intervals, (i.e., daily for a week and hourly for a day) to test the efficiency with which weekly samples measure the total inputs or discharges.

Since rainfall directly on the Lake represents a major source of water, the inputs of nutrients and dissolved solids in rainfall will have to be measured. Although the exact procedure for collecting rainfall samples has not been worked out, one method would be to locate rain collecting devices at pump stations around the Lake, which could be maintained by pump station personnel.

The analysis necessary to conduct this study are field, physical,major ion and nutrient determinations on all lake samples. Alkalinity and pH values for the input-output and rainfall samples will be measured in the lab.

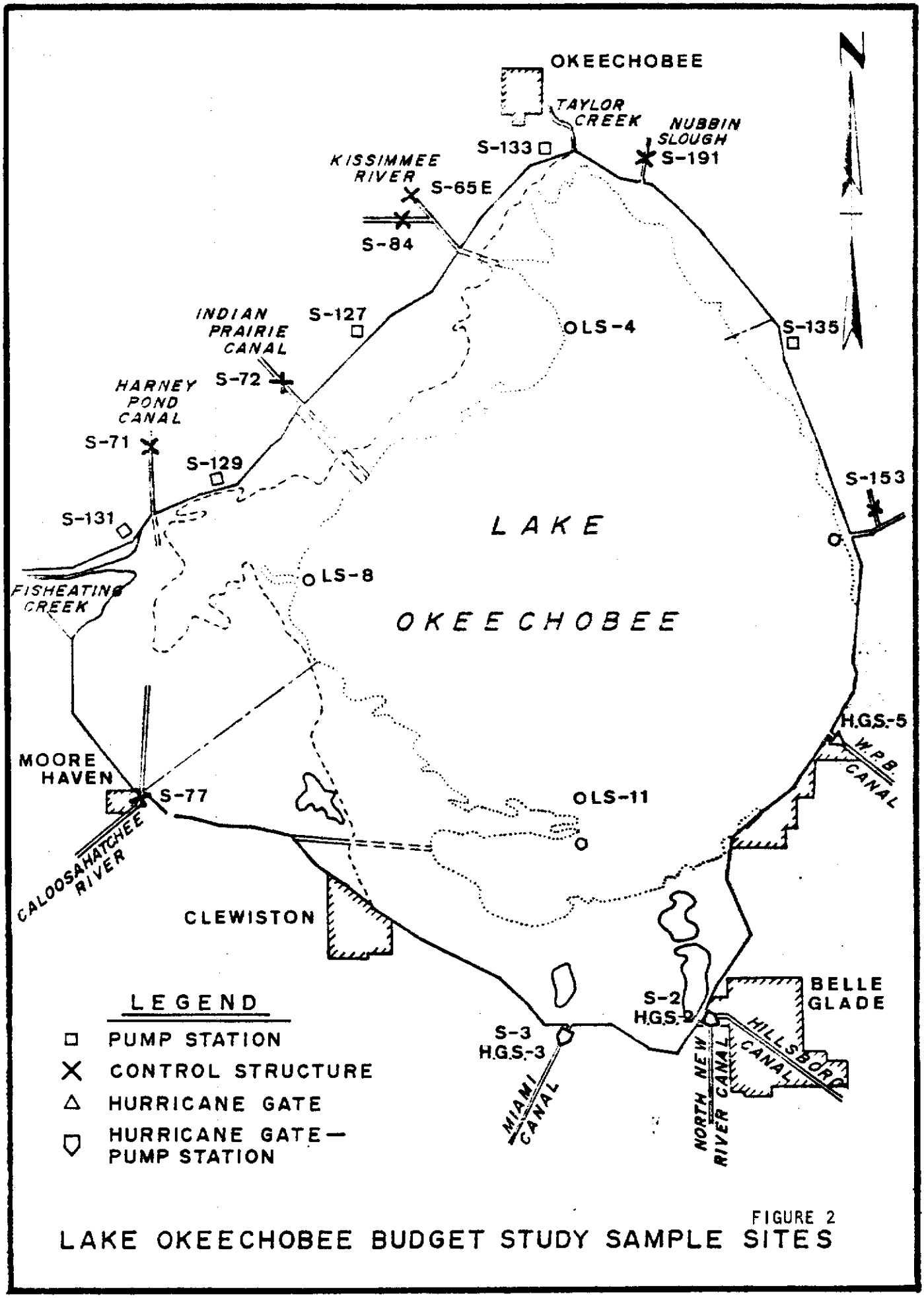


FIGURE 2

LAKE OKEECHOBEE BUDGET STUDY SAMPLE SITES

## CIRCULATION

A basic understanding of the circulation patterns to be found within the body and littoral areas of a lake is a necessary step in any sequence of events whose purpose is to provide an explanation for conditions presently found to exist, as well as to provide the capability of predicting future changes resulting from proposed altered conditions.

In this segment of the overall study, it is proposed to evaluate the circulation patterns under what is considered the prevalent boundary conditions anticipated for Lake Okeechobee. These can be grouped into three major categories:

1. Water stage regimen.
2. Significant inlet-discharge configuration.
3. Wind runup currents.

It should be considered a strong possibility that the geo-morphologic characteristics of the Lake, when they change due to fluctuating water depth, will have a significant influence on the patterns of water distribution as it flows into and out of a lake. This possibility seems to be even stronger in a lake such as Okeechobee with its extremely shallow, saucer-like shape. Although only small changes are reasonably anticipated in the Lake depth, these increases in depth can be a significant percentage of the total depth present in the Lake.

The configuration of the inlets and outlets of a body of water will obviously exert a strong influence on the flow patterns within that water body. Lake Okeechobee is now altered from a natural state in such a manner as to allow, within limits, for arbitrary choices to be made concerning the combination of inflow/outflow points. The likely possibility of certain inflow/outflow conditions being in use a significant percentage of the

time will be evaluated using available historical data and projections for future conditions. Definition of flow patterns under these conditions will be investigated with the aim of developing sufficient understanding of the phenomena so as to be able to chart the flow of water through the Lake under various steady-state boundary conditions.

Boundary layer interaction between fluids moving with different velocities creates shear stresses in the fluids. These stresses serve to impart motion to fluid which may not be apparent until closer examination is made. This condition, using wind across water as an example, would tend to set the water surface in motion in the direction of the wind. The velocity and depth to which this motion is imparted is primarily a function of wind velocity and time of exposure. When the water, which has been set in motion by the wind, meets an obstacle, (such as the shore), the existing momentum causes it to pile up in front of the obstacle. Due to the instability of this surcharge, a countercurrent along the bottom of the water body is formed. This is the third major circulation influence which we propose to evaluate.

In addition to the counter currents, wind induces waves and their associated turbulence vertically within a lake. Depth of mixing, duration of mixing, periods and areas of the lake which can be expected to mix under average annual wind conditions will be determined. It is expected that predictions as to the amounts of the lake which reasonably could be expected to stratify and for what period of time, will emerge from this evaluation.

An attempt will be made to determine the interchange of water between the marsh and open water areas of the Lake. The possibility of significant movement of water through the marshes needs to be evaluated in order that a better understanding of the likelihood of a beneficial water quality effect

of the marsh on the Lake can be determined. There is also the possibility that the water within the marsh areas derive primarily from rainfall directly on the marsh body itself.

The aim of the entire circulation segment of the study is to be able, for any given set of boundary conditions (meteorologic, hydrographic, and physical alterations) to predict the path water will take through the Lake after defining its starting point. The circulation patterns developed in this portion of the overall study will be used in the biological and chemical phases of the investigation. The information will assist in evaluating marsh roles in the nutrient cycle in the Lake, and defining the temporal nature of water quality within the Lake.

It is felt that serious consideration should be given to developing a model of the Lake during the course of this study. This model would be fundamentally a circulation (or transport) model, onto which subroutines depicting other activities could be attached for the purpose of predicting changes due primarily to changing physical conditions within the Lake as a result of water management practices thought to be necessary or desirable.

Chemical data for development and testing of simulation models of Lake Okeechobee will be provided. The exact nature of the data, sampling locations and methods must be worked out in coordination with the physical studies themselves.

The anticipated input of chemical data into physical studies would include tracing of point discharge water masses such as Kissimmee River water and water backpumped from agricultural areas south of the Lake. Also, chemical studies may be useful for determining water exchanges between littoral areas and open Lake zones.

These tasks may be accomplished by specific conductivity, conservative ion measurements, or dye tracing studies.

## LITTORAL ZONE

### DOCUMENTATION AND ANALYSIS OF MARSH AREAS

Vegetation transects will be established at key locations in the marsh with permanent markers installed along these transects. The transects will be surveyed to establish an elevation profile of these areas. Each species of vegetation will be recorded along the transects and their locations established in relation to permanent markers. Transects thus established should provide information that can be used to document elevation ranges of major vegetation associations of the marsh. This information can then be studied in relation to sediment soil types and water level records to determine conditions responsible for the presence of these associations.

Major vegetation associations will be mapped from aerial photography and will ultimately be combined to produce a scale vegetation map of the marsh. Area (acres) occupied by these associations will be determined from the vegetation map. From topographic maps of the marsh, areas between contour lines can be determined.

Standing crop of forage fish and invertebrates will be used to document productivity of the marsh in relation to water depth, water fluctuations and major vegetation associations. Samples for productivity determinations will be taken at strategic points along established vegetation transects.

Existing information from various state and federal wildlife and conservation agencies will be utilized for evaluation of sport fish and rough fish populations of the marsh and waterfowl and aquatic bird utilization.

The three vegetation transects to be studied are shown on Figure 1.

(1) Indian Prairie Canal:

Transect runs parallel to the canal approximately one mile south of the canal.

(2) Chancey Bay:

Transect starts at a point approximately one-half the distance

between Nubbin Slough and the St. Lucie Canal and runs in a southwesterly direction out to the open Lake.

(3) Moore Haven:

Transect runs from approximately the junction of the Old Moore Haven Canal and Rim Canal northeasterly out across Observation Shoals to the open Lake.

WATER QUALITY

Water quality within the littoral zones of the Lake will be monitored bi-monthly. Samples will be taken along transects currently being surveyed for vegetation studies. When correlated with vegetation studies and physical studies of mixing between the open lake and littoral zones, the water quality data will provide data for assessing the importance of marsh areas to the Lake itself.

Transect water sampling stations will be located at the Lake and shore ends of each transect. The shore end stations will of course depend on Lake stage. Stations between the ends of the transects will be spaced at approximately one mile intervals, where possible, with a minimum of at least one station between the end stations. The number of stations will probably vary between ten in the dry season to sixteen in the wet season.

Analysis of the samples will include field determinations of temperature, specific conductivity, pH and dissolved oxygen when possible. Complete nutrient and major ion analysis will be run in the lab along with alkalinity titrations.

Parameters to be included in nutrient and major ion analysis are shown in Table 1.

Sediment or soil analysis may be run twice a year for comparison with open water lake sediments.

## PROJECTIONS

Information from the proposed littoral studies should allow predictions to be made as to the maximum Lake stages that would benefit the marsh. Losses in marsh area and productivity resulting from exceeding or going below this stage to comply with any proposed Lake stage could then be evaluated. This study should also be valuable in assessing alternatives to various aspects of the proposed Lake Okeechobee Project. For example, extending present levees on the northwest portion of the Lake back to the highway before any major development can take place, may allow both higher Lake stages and an increase in marsh area.

## BENTHIC ZONE

### SEDIMENTS

The floor of the Lake will have on it, to some extent, deposits of unconsolidated material. This material may be either the organic remains of plants and animals or inorganic in nature. It is proposed to sample the bed of Lake Okeechobee to gather information concerning the type, distribution and origin of whatever unconsolidated sediments are found on the bottom of the Lake. Cores taken on a grid pattern with random samples to evaluate the sufficiency of the grid, will be used to develop a sediment map of Lake Okeechobee.

Data to be obtained will include sediment depth, changes in sediment composition with depth, and the physical and chemical composition of the sediments. The degree of resistance to resuspensions will be evaluated to determine how wind-induced turbulence and the bottom sediments pphysically interact. Should it be found that the sediment cores exhibit layering and appear to be undisturbed, it may be possible to estimate some of the history of the Lake. In the absence of this layering of the sediments, an excellent indication of periodic complete mixing of the sediments by wind-induced water turbulence is presented.

The information on sediments will be used to correlate with the vegetation mapping project to further develop the understanding of existing plant distributions as well as predictions for other considered conditions. The sediment mapping will also help in evaluating the effect of source-sink studies on the effects of sediments on water quality proposed under the chemical section.

### SEDIMENT ANALYSIS AND SEDIMENT WATER INTERCHANGES

Samples of Lake Okeechobee sediment, together with samples of water above the sediment, will be analyzed to determine the extent to which the sediments

act as sinks and sources for nutrients and dissolved solids as suggested by the U.S.G.S.[1] report on the Lake. Also, attempts will be made to measure exchanges of nutrients and dissolved solids between the sediments and water column.

Sample sites for sediment studies are the same as the water quality monitoring stations (Stations 1-9, Figure 1). However, the sites may be changed as physical and geological data on the types and distribution of sediments in the Lake become available.

Samples of sediments (preferably cores) and water will be obtained during the wet season (July) and dry season (February) to determine if climatic cycles are related to exchanges. The water sample will be analyzed for major ions and nutrients. Similar analysis will be performed on the whole sediments and interstitial water of the sediments, including redox potential measurements. Hopefully, long enough cores can be obtained to allow analysis of several sections of a core to determine if the nature of the core varies with depth of sediment.

In situ experiments will be set up to measure exchanges of components (especially phosphorus, nitrogen, calcium, magnesium and iron) between sediments and the water column. Pairs of cylinders will be inserted into the bottom with one cylinder enclosing a column of water exposed to the sediments and the other enclosing water not exposed to sediments. Any changes in concentration of a particular element in the water enclosed in the cylinder with the open bottom, but not found in the other cylinder, may be attributed to the sediments. Hopefully, such changes will be noticed within a short time (several days).

Depending on the success and feasibility of such experiments, they will be repeated at the core sampling sites during the wet and dry cycles of the year.

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[1] Joyner, B.F., Appraisal of Chemical and Biological Conditions of Lake Okeechobee, Florida, 1969-70, Open File Report 71006, U. S. Geological Survey, Tallahassee, Florida, 1971.

## ADDITIONAL STUDIES

Further documentation of the hydrology and geomorphology of Lake Okeechobee is necessary to support the other biological, chemical and physical studies of the Lake.

### HYDROLOGY

At this time, a large body of information is available upon which hydrologic relationships can be established. Further necessary refinements in data collection may become apparent as preliminary analysis begins.

A complete water budget for the Lake system will be established. This budget will attempt to not only account for all water crossing the boundary of the system (rainfall, inflow, outflow, evaporation, transpiration, and seepage), but also to budget water in the subsystem of the Lake itself.

Meteorologic data will be collected around, and more importantly, within, the confines of the Lake. Existing information clearly shows that rainfall patterns over the body of the Lake are greatly different than those over the surrounding land masses. Rainfall, wind direction and velocity, air and water temperature, relative humidity, solar radiation intensity, and wave height will be recorded.

Some of the relationships to be developed include stage and discharge hydrographs, stage and discharge frequency distribution curves, stage-surface area curves and rainfall-discharge relationships. This information will be necessary to understand the natural inputs and influences on any scheme of control put forth for evaluation as to its effect on the total Lake system.

### GEO-MORPHOLOGY

It is proposed that the necessary field work, namely, a hydrographic survey, be made of Lake Okeechobee. Indications of the type of data which needs to be provided for usage by other segments of the comprehensive study are listed as follows:

| | |
|---|---|
| Area | Shore Length |
| Mean Depth | Littoral Slope |
| Maximum Depth | Number of Islands |
| Area of Depth Zones | Area of Islands |
| Volume of Depth Zones | Shore Length, Islands |

Here, again, possible changes in water level for the Lake will cause signficant changes in certain characteristics of the Lake. For proper definition, a series of values of key geo-morphometric characteristics will be computed using the reasonably anticipated maximum-minimum stage ranges for the Lake.

The geo-morphometric conditions will be important parameters in the evaluation of the marsh systems along with the sediment maps for vegetation change projections. Proposed changes in water levels will create shifts in marsh location, depth, and soil-water depth relationships which may all be definitive in marsh establishment and survival pattern.